Fabrication and Characterization of Surface Textured GaInN Vertically Structured Light-Emitting Diodes with Omni-Directional Reflectors as Light-Extraction-Enhancement Technique

By

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ABSTRACT

A new generation GaN-based light-emitting diodes (LEDs), vertical LEDs, take advantage of conductive substrates. This class of LEDs significantly suppresses current crowding and self-heating effects which are inherent to sapphire substrate in lateral LEDs. However, relatively little research has been conducted related to fabrication of vertical LEDs on bulk GaN substrate. The benefits of this approach extend beyond simplification of the fabrication process; GaN epitaxial layers are lattice-matched to bulk GaN substrates (native substrates) and therefore have a lower dislocation density compared to layers grown on foreign substrates (non-native substrates), which improves device performance. Thus far, impacts of integrated optical elements such as high-reflectivity omnidirectional reflectors (ODRs) and N-face *n*-type GaN surface texturing on GaN vertical LEDs with bulk GaN substrate have not been investigated. In this master thesis we present GaInN LEDs on bulk GaN, grown on the Ga-face of the *n*-type GaN (0001), emitting at λ = 440 nm, with the backside *n*-type ohmic contacts fabricated on the N-face GaN ($000\bar{1}$). The triple-layer ODR structure, consisting of a SiO_2 low-index layer perforated by an array of Ag metal micro-contacts is placed on top of the *p*-type GaN. In addition, ray tracing simulations indicate that total internal reflection is highly suppressed by employing hexagonal pyramid-shaped surface patterning. For encapsulated devices, extraction efficiency is increased by as much as 60%, while 200% improvements are possible for unencapsulated devices. Pyramid-shaped patterning of N-face GaN have been achieved by potassium hydroxide (KOH) wet etching at room temperature. Our simulation results agree with experimental work in demonstrating a significant improvement in the light output power and the external quantum efficiency.